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Legal aspects of Air traffic management based on satellite navigationⁱ

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Satellite based navigation system have totally changed our concept of regulation in Air traffic Management as the legal regime or liability regime hitherto applicable for territorial service seems no longer support new global or at least regional ATM services offered by the various Providers. The legal issues related to satellite navigation vary and depend up on numerous factors including precise commercial application. The satellite navigation will be one of the key enabling technologies of future transportation and airspace management system. Thus this paper addresses the legal issues in air traffic management based on SATELLITE BASED AUGMENTED SYSTEM (SBAS).

This article will address issue of responsibility of state in the light of Liability convention 1972 and Chicago convention besides examining responsibility of service provider under private law (contract) to the extent of the application principle of CAVEAT EMPTOR as to the accuracy of positioning of aircraft based on the satellite signal.

The liability regime between service provider and beneficiary or passenger is either concluded under contract or under various Air law conventions like Warsaw conventions or Montreal conventions. However moot point arise as to the liability to third party on account of accident to the Aircraft caused by wrong signal from satellite or by other numerous reasons like interference with the satellite by a foreign state or by its subjects . Since issue is related to Space law and Air law, this article will examine it under Liability convention 1972 and under Rome Convention 1952. This article aims to achieve underlying importance for broader regulation by states for satellite based ATM as present regime continue to be vacuum in area resulted from outer space activities.

1. Introduction

“Air Traffic Control’s primary objective is to ensure flight safety: pilots in their cockpit are to a large extent « blind » to the exterior world and, given the aircraft speed and trajectory complexity, it is necessary to control them from the ground in order to make sure that of course there are no accidents, but also to ensure the overall fluidity and efficiency of traffic flows. Air Traffic Control (ATC) is based on two main pillars: “surveillance”, which enables ground operators to know precisely where the aircraft are, and the “controller”, who

manages the safety of flights. Ever since the implementation of radars in the 70s-80s as surveillance means, air traffic control has not evolved much: ATC is essentially "craftsmanship", and relies entirely on the controllers' individual capability to handle always more traffic. Even though air transport has exceptionally good reliability and safety records, to a large extent thanks to the high quality of work performed by air traffic controllers, this craftsmanship is becoming anachronistic: in the information society era, communications between controllers and pilots are still using the voice-radioⁱⁱⁱ!"

The current Air Traffic Management (ATM) is based on ground navigational system such as radar and voice communications experience difficulty in meeting growing demand of air traffic. Despite economic recession ICAO^{iv} expects moderate growth of air traffic of 3.3 percent to 5 percent during 2010-11^v. According to aircraft manufacturer Airbus, global air passenger traffic is set to increase by over 150% over the next 20 years, representing an annual growth of 4.7%. The size of the world's passenger aircraft fleet will double in number from 14,016 in 2008 to 28,111. The fastest growing regions will be India, China and Africa, driven by deregulation, economic growth, population growth and inter-regional trade. 2007, traffic slowed to a 2% growth in 2008 and this year will see an expected decline of 2%. By next year, a worst case scenario suggests zero growth and a best case of a return to growth of 4.6%. The plane-maker says the greatest demand for passenger aircraft will be from airlines in Asia-Pacific and emerging markets. The region that includes China and India will account for 31% of the total, followed by Europe (25%) and North America (23%). In terms of domestic passenger markets, India (10%) and China (7.9%) will have the fastest growth over the next 20 years. The largest by volume of traffic will remain domestic US.

Airbus says the main drivers of future traffic growth will be:

- growing Middle East passenger and cargo hubs;
- in Asia, more people able and wanting to fly everyday;
- low-cost carriers in Asia growing in number and traffic share;
- more potential through deregulation, particularly in Asia and Africa; and
- growing urbanization and a resulting increased demand between major cities

It is in this scenario global Air Traffic Management has to address to a system that provides a greater capacity for required surveillance in air space with assured safety. The introduction of satellite-based air navigation services to replace many of the existing line-of-sight systems represents a quantum step forward for civil aviation. Following comprehensive studies over several years, the global "communications, navigation and surveillance/air traffic management (CNS/ATM) systems" concept was endorsed by the ICAO Tenth Air Navigation Conference in 1991 and by the 29th Session of the ICAO Assembly in 1992.

The Global Navigation Satellite System^{vi} is poised to be one of the most critical technologies in the 21st century and considered as an important element of the communications, navigations, surveillance etc, intended to provide worldwide coverage. At present the satellite navigation technologies like Internet is becoming a global means and is finding an application practically in all areas of the activities of a man.

Legal aspects of satellite based ATM is grappled mainly around lack of legislative will of world body like ICAO to regulate beyond air space as issues are surmounted on the interface of space law and air law.

The early stages of space activates only saw the participation of very few states. All the investment towards the space sector was purely from the government exchequer and because of this reason; all the space treaties only mention the rights, obligation and responsibilities of the state government. As stated above, all the international instruments governing outer-space were build-up and agreed before the high influx of commercial space activities and therefore, do not sufficiently take into account the implications and aftermath of the growing volume of commercial space activities.

ICAO is a global public international organization and its mandate originated from Chicago convention^{vii} cannot go beyond mandate to regulate on non sovereign area of outer space. It is in this backdrop this paper addressing various legal aspects in the light of potential issues.

2. Satellite based ATM

Global Navigation Satellite Systems currently have two core constellations – Global Positioning System (GPS) of the United States and the Global Navigation Satellite System (GLONASS) of the Russian Federation. Other similar systems are the upcoming European Galileo positioning system; the proposed are COMPASS-Bediou Navigation System of China; Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) of France and the Indian Regional Navigation Satellite System (IRNSS) of India. Almost all satellites are launched in order to provide service to people on earth. Satellites are routinely used to support sustainable development. Satellite is mainly used as source information for decision making or to transmit information.

Current and Planned System Providers^{viii}

The United States: Global Positioning System (GPS)

GPS is a United States space-based radio-navigation system that provides reliable positioning, navigation, and timing services to users on a continuous worldwide basis—freely available to all. The outstanding performance of GPS over many years has earned the enduring confidence of millions of international users. With its ongoing modernization programme, GPS will continue to provide superb quality and performance in the future.

The Russian Federation: Global Navigation Satellite System (GLONASS)

The Russian navigation satellite system, GLONASS, is based on a constellation of active satellites which continuously transmit coded signals in two frequency bands, which can be received by users anywhere on the Earth's surface to identify their position and velocity in real time based on ranging measurements. In the future a third frequency for GLONASS signal transmission will be introduced. In some areas of application, the use of combined GPS, GLONASS and Galileo constellation appears to be preferable option.

The European Community: European Satellite Navigation System (GALILEO)

GALILEO, an initiative launched by the European Commission and the European Space Agency, will be a global navigation satellite system, owned by the European Community, providing highly accurate, guaranteed global positioning services under civilian control. The Galileo Open Services signal will be interoperable with the GPS civil signal, as well as with GLONASS.

China: COMPASS/BeiDou

The existing three-satellite COMPASS/BeiDou navigation system has played an important role in offering efficient positioning, timing, communication services and differential GPS information in surveying, telecommunications, transportation, meteorology, forest fire prevention, disaster forecast and public security areas. On the basis of the COMPASS/BeiDou Navigation Test System, China has started to build a system with global coverage.

Current and planned augmentation system providers for ATM

A **satellite-based augmentation system (SBAS)** is a system that supports wide-area or regional augmentation through the use of additional satellite-broadcast messages. Such systems are commonly composed of multiple ground stations, located at accurately-surveyed points. The ground stations take measurements of one or more of the GNSS satellites, the satellite signals, or other environmental factors which may impact the signal received by the users. Using these measurements, information messages are created and sent to one or more satellites for broadcast to the end users.

In air traffic management SBAS provides signals from core constellations, GPS or GLONASS or from Interoperable systems through ground reference stations. Each station in network relays the data to master station where correction information for specific information is computed; corrected message is prepared and uplinked to a GEO stationary communication satellite via ground up link station. This message is broadcasted to receivers onboard of aircraft flying within coverage area of system.

WAAS: The **Wide Area Augmentation System (WAAS)** is an air navigation aid developed by the Federal Aviation Administration (FAA) of US to augment the Global Positioning System (GPS), with the goal of improving its accuracy, integrity, and availability. Essentially, WAAS is intended to enable aircraft to rely on GPS for all phases of flight, including precision approaches to any airport within its coverage area.

EGNOS: The **European Geostationary Navigation Overlay Service (EGNOS)** is a satellite based augmentation system (SBAS) under development by the European Space Agency, the European Commission and EUROCONTROL^{ix}. It is intended to supplement the GPS, GLONASS and Galileo systems by reporting on the reliability and accuracy of the signals

MSAS: **Multi-functional Satellite Augmentation System (MSAS)** i.e. a satellite navigation system which supports differential GPS (DGPS) designed to supplement the GPS system by reporting (then improving) on the reliability and accuracy of those signals. Tests had been

accomplished successfully; MSAS for aviation use was commissioned on September 27, 2007^x.

GAGAN: The **GPS Aided Geo Augmented Navigation** or **GPS and Geo Augmented Navigation** system (GAGAN) is a planned implementation of a regional Satellite Based Augmentation System (SBAS) by the Indian government. It is a system to improve the accuracy of a GNSS receiver by providing reference signals. The Rs. 7.74 billion (774 crore) project is being implemented in three phases through 2008 by the Airport Authority of India with the help of the Indian Space Research Organization's (ISRO) technology and space support. The goal is to provide navigation system for all phases of flight over the Indian airspace and in the adjoining area. It is applicable to safety-to-life operations, and meets the performance requirements of international civil aviation regulatory bodies. The final, operational phase of GAGAN is likely to be completed by May 2011. *Gagan* is the transliteration of a Hindi/Sanskrit word for the sky^{xi}.

3. Law of responsibility and liability

Law of responsibility is concerned with the determination of whether there is wrongful act for which the wrong doer is to be held responsible. Some time term "responsibility" interchangeably used with term "liability" which in common parlance understood obligation to pay compensation. In air law responsibility is on state to provide air navigation facilities to facilitate international air navigation^{xii}. In the context of space law, state shall bear international responsibility for national activities in outer space^{xiii}. Law of liability is specific in air law as to claim of passengers and third parties as envisaged in Montreal Convention 1999 and Rome Convention 1952. In space law launching state shall be absolutely liable to pay compensation for damage caused by space object on the surface of the earth or to aircraft flight under Liability Convention 1972^{xiv}. Nuances and intricacies of issues emanates from application of air navigation based SBAS could not contemplated while provisions in Air law and Space law were drafted. Therefore legal basis for "responsibility and liability" should be examined in the light potential claims on the interface of air and space law.

Essentially four types of claimants may be found in SBAS based ATM

- 1 Air carrier against ATM service provider
- 2 Passenger in aircraft
- 3 Third party
- 4 ATM service provider against Signal provider

Claim of Air carrier: It is not necessary for air carrier to have contractual obligation with the ATM service provider as later deemed to provide air navigation facilities to every contracting states under article 15 of Chicago convention on uniform conditions. Problem may arise as to application of law of in the claim of air carrier against ATM service provider especially for foreign air carrier for an accident in a country other than where ATM service provider is located. "Much of private air law however is not unified, substantially or as to conflict rules by international conventions. In these areas national private law will apply, the law of conflicts (in common law terminology) or private international law (in civil law terminology) serving to determinate which national laws will apply in a fact pattern with international elements. International elements are of course, dominant in the practice of air transport industry: these areas of non unified private air law are principally, but not

exclusively, product liability air traffic control and air port liability"^{xv}... Actor sequitor forum rei –A pursuer follows the forum or court of defendant. Under Hague convention of private international law on traffic accidents ^{xvi} the applicable law is the internal law of the state where the accident occurred. It would be difficult to sustain tortuous claim in a country where sovereign immunity would apply. Thus jurisdiction can be either in country where accident occurs or in country where ATM service provider is located, however such claims have to be settled based on the broad principles of international responsibility of state. According to Prof. Brownlie

"One can regard responsibility as a general principle of international law , a concomitant of substantive rules and of the supposition that acts and omissions may be categorized as illegal by reference to the rules establishing rights and duties. Shortly, the law of responsibility is concerned with the incidence and consequence of illegal acts and particularly the payment of compensation caused"^{xvii}

Liability of ATM service provider to carrier is part of non conventional private international law, as mentioned above claim has to be preferred in a jurisdiction where accident occurred or where ATM service provider is located. However law that would be applicable in such claim is of country where accident occurred. "ATC Liability will normally be extra-contractual (tortuous) in nature, governed by *lex loci defect*"^{xviii} .

Claim by passenger: Claim by passenger is found base in Warsaw convention^{xix} or Montreal Convention^{xx} as such claims are related or arising from terrestrial cause of action, even though it may have origin from satellite or from augmented system, nevertheless, immediate tortfeasor being aircraft or ATC provider, their claim rest under relevant conventions." Air traffic control service providers maybe liable for damage to passengers (and their estates), shippers and third parties on the ground if, through wrong or faulty ATC instructions, they cause an aircraft to crash or collide"^{xxi}. However such claims is generally are non contractual and tortuous in nature. As mentioned earlier providing air navigation facilities rest with State, it may be difficult to sustain such claims in countries where sovereign immunity operates. Under United States Foreign Immunities Act of 1976 foreign state shall be immune from the jurisdiction of the courts of the United States except such in which the action is based up on a commercial activity carried on in the United States by the foreign state. Or up on an act performed in the United States in connection with a commercial activity of the foreign state elsewhere. Similarly United Kingdom State Immunity Act 1978 Or 1985 Foreign State Immunity Act of Australia affords immunity to States from the jurisdiction of courts in United Kingdom or Australia. In India under section 86 of Civil Procedure Code, a suit against foreign state is maintainable with consent of Central Government. Perhaps in the light of Article VI of Outer space treaty which mandate that State shall bear international responsibility for national activities, state immunity principle may be denuded for action in claims against ATC service provider for faulty or erroneous signal from satellite by applying Rule found in Article 27 of the Vienna Convention on the Law of Treaties which lays that ' A party may not invoke the provisions of its internal law as justification for its failure to perform a treaty'.

Third party claims: The third party is having limited remedy against Air line carrier under Rome Convention 1952^{xxii}. Signatories to the Rome Convention 1952 are only few countries (49 countries). In countries where Rome Convention is applicable, the third parties cannot resort for other remedies as Article 9 specifically excludes liability otherwise than through provisions of Rome Convention .In countries where Rome convention does not apply, law applicable to damage done by aircraft on the surface usually based up on fault or

negligence. Therefore the liability to be fastened is on proof negligence, when aircraft involves in an accident resulting damage to third party due to error of signal from satellite, on which liability could be fastened? Which law would apply? Are necessarily to be answered with reference to space law, as seemingly negligence originate from outer space. This issue dealt in next title under 'claims of ATM service provider against Signal provider'.

Claim of ATM service provider against signal service provider: There are many potential reasons for failure or erroneous signal from satellite which may result in accident. ATM service provider may have to resort to non contractual liabilities, but it may be a problem to establish for want of proof of negligence. It is in this backdrop legal position under space law has to be examined especially Liability Convention 1972. Article II of Liability Convention provide "A launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft flight". The liability is absolutely liability. Does Liability convention contemplate any liability emanates from signal from satellite? What is space object then? It may be recalled Liability Convention was drafted before influx of commercial activities in outer space. Like all other conventional navigation systems, the SBAS is subject to errors that can degrade the precision of the system. The errors are Ionospheric error, Tropospheric error, Selective Availability, Satellite clock error, Receiver clock error, Multi path error, Receiver error, Satellites Ephemeris error and Geometrical error etc. It is not necessary that Satellite has caused any error on other hand signal error results in accident, since Liability Convention does not undertake any enquiry as to culpability of accident as accident itself speak about cause, merely because of involvement of space object, it is difficult to say involvement of signal from satellite is contemplated under Liability Convention. Signal from satellite cannot be equated with space object, in this context space object means which can directly cause accident, as underlying principle of "absolute liability" in Article II of Liability Convention denote. To quote Dr Abeyrante *"Admittedly, neither the Outer Space Treaty nor Liability Convention explicitly provide remedies for damage caused by technology and communication provided through space objects^{xxiii}. However the 'common interest' principle and liability provisions of these two Conventions can impute culpability to states"*. There is no provision under space law to sustain claim under relevant Conventions or Treaties, nevertheless as argued by Dr Abeyrante international responsibility of state cannot be avoided under the principles of international law

4. Signal Precision and Product liability

"The most significant error occurs when the satellites signal goes through the earth atmosphere. This is a layer of electrically charged particles located approximately between 130 and 190 Km above the surface of the earth. As the GPS signal travels through the ionosphere, it is slowed down in a proportion that varies according to time of days, solar activity and series of the other elements. Ionospheric delays may be forecast and an average correction applied to the GPS position. Another error is caused by water vapour in the atmosphere which delays the GPS signal and also contributes to degrade the position of the system"^{xxiv}. Essentially most legal system recognize that the manufacturer of aeronautical products, has triple duty; a duty to design safe product duty to manufacture a safe product and duty to warn against dangers in using product. Under article 1 of EC directive (87/374 EEC) on product Liability for European Union, the producer shall be liable for damage

caused by defect in his product. Product liability normally decided according to national laws and the principles of 'strict liability'. "Satellite based navigation system for ATM can be termed as a product. It employs various techniques in system design to correct ionospheric impact on signal. Though system is deployed after meeting ICAO SARP and Technology Demonstration System (TDS), the product liability would exist for inaccurate service due to design or defect in system^{xxv}" However liability on Signal provider may not exist for error or for lack of precision due to atmospherical impact as every prudent man must know such impact likely to affect satellite signal. The error introduced by the ionosphere into GPS signal is highly variable and difficult to model^{xxvi}. The influence of the ionosphere and strategies to isolate its effect are issues of major concern for GPS positioning and navigation application^{xxvii}. The inaccuracy or degrading factors are not result of defect or design of the system. Infact system is designed taking into consideration of ionospheric impact on signal, and therefore it would be justifiable defence for service provider to defend themselves relying principles of 'Caveat emptor' which means 'let the buyer beware'. The technological constraints or barriers in atmosphere mitigate liability of signal provider on the above principle of law.

5. Interoperability

According to IEEE^{xxviii} definition interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged. In GNSS context, interoperability can be understood such that individual GNSS components should be designed, built and operated in such a way that they do not 'jam' each other and allow one to combine their signal in a navigation service of superior quality. ICG (International Committee on Global Navigation Satellite System) is a forum established on a voluntary basis as an informal body to promote cooperation, as appropriate, on matters of mutual interest related to civil satellite based positioning, navigation, timing and value added services, as well as the compatibility and interoperability of global navigation satellite system while increasing their use to sustainable development. Within the ICG is the providers forum, consisting of those countries operating GNSS system or with plans to develop one. Providers forum adopted Definition of interoperability as follows

'Interoperability refers to the ability of global and regional navigation satellite systems and augmentations and service they provide to be used together to provide better capabilities at user level than would be achieved by relying solely on the open signal system'

Interoperability of GNSS poses innumerable issues to end user with regard to claim and jurisdiction^{xxix}. Certainly interoperability signifies involvement of multiple GNSS providers located in different jurisdictions having conflicting domestic laws. The task of claimant in such context is to identify appropriate jurisdiction and law applicable for such claim. ICAO identifies that substantive law may be reasonably adequate to determine or apportion liability from accidents involving failure or malfunction of GNSS systems, procedural rules and, in particular, the applicable rules on jurisdiction may not be adequate to bring all parties to the court in order to ensure prompt and equitable compensation in these cases, in particular application of sovereign immunity and related principles may in many cases render court action against foreign states or foreign governmental entities providing ATC or

GNSS signals, facilities and services in countries other than their home states difficult or impossible^{xxx}.

ⁱ Copyright with author

ⁱⁱ A lawyer practicing at High Court of Kerala, India and having master from Paris XI in space and telecommunication law.

ⁱⁱⁱ http://ec.europa.eu/transport/air_portal/traffic_management/sesame/index_en.htm viewed on 12/04/2010

^{iv} A specialized agency of UN created in 1944 to promote safe and orderly development international aviation throughout the world.

^v ICAO news release PIO08/09

^{vi} Global Navigation Satellite System (GNSS) is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. A GNSS allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few metres using time signals transmitted along a line of sight by radio from satellites. Receivers on the ground with a fixed position can also be used to calculate the precise time as a reference for scientific experiments.

^{vii} Chicago Convention 1944, on international civil aviation signed at Chicago by contracting states.

^{viii} Booklet published by international committee on Global navigation satellite system

^{ix} Eurocontrol is the European Organisation for the Safety of Air Navigation. Founded in 1963, it is an international organisation working for seamless, pan-European air traffic management. Eurocontrol is a civil organisation and currently has 38 member states; its headquarters are in Brussels.

^x Source http://en.wikipedia.org/wiki/Multi-functional_Satellite_Augmentation_System viewed on 14/04/2010

^{xi} Source http://en.wikipedia.org/wiki/GPS_Aided_Geo_Augmented_Navigation viewed on 14/04/2010

^{xii} See art 28 of Chicago convention

^{xiii} Art VI of Outer Space Treaty (a treaty on principles governing the activities of states in the exploration and use of outer space ,including the moon and other celestial bodies) .This treaty forms basis of international space law signed and came into force in the year 1967

^{xiv} Convention on international liability for damage caused by space objects entered in the year 1972

^{xv} Page 67 chapter Five The Law and policy of air space and outer space , A comparative approach By P.P.C Haanappel pub: Kluwer Law international

^{xvi} Convention on the law applicable to traffic accidents (concluded 4 may 1971, entered into force on June 1975

^{xvii} Principles of public international law pub: Oxford Clarendon Press

^{xviii} The Law and policy of Air space and outer space page.92 by Prof P.P.C Haanappel

^{xix} The **Warsaw Convention** is an international convention which regulates liability for international carriage of persons, luggage or goods performed by aircraft for reward signed in 1929.

^{xx} The **Montreal Convention**, formally the **Convention for the Unification of Certain Rules for International Carriage**, is a treaty adopted by a Diplomatic meeting of ICAO member states in 1999. It amended important provisions of the **Warsaw Convention**'s regime concerning compensation for the victims of air disasters.

^{xxi} P.91 of The law and policy of air space and outer space by Prof P.P.C Haanappel

^{xxii} Rome Convention applies only to damage caused by foreign civil aircraft ,for damage caused by national aircraft only local law would apply.

^{xxiii} State responsibility in classical jurisprudence reflections on the GNSS by Dr Abeyrante article pub: Annals of Air and Space Law V XXIII (1998)

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- ^{xxiv} Communication navigation and surveillance/ATM beyond 2012 by Arjun Sing Air port Authority of India ,source <http://www.gisdevelopment.net/technology/gps/ma04082pf.htm>
- ^{xxv} Legal aspects relating to satellite navigation in air traffic management with specific reference to GAGAN in India copy right with IAF , presented in IAC 07author .A.Mohamed Mustaque
- ^{xxvi} Assesment of ionosphereic impact on LAAS using WAAS super truth data by Ming Luo and other sStanford University
- ^{xxvii} *ibid*
- ^{xxviii} IEEE ,Institute of Electrical and Electronic Engineers , a nonprofit organization ,is the world`s leading professional association for the advancement of technology
- ^{xxix} Interoperability of GNSS ,legal issues and implications under private international law ,presented at IAC 09 by A.MOHAMED MUSTAQUE copyright with IAF
- ^{xxx} Report to the 35th session ICAO Assembly for consideration.



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Improving air traffic control and air traffic management is currently one of the top priorities of the global research and development agenda. Massive, multi-billion euro programs like SESAR (Single European Sky ATM Research) in Europe and NextGen (Next Generation Air Transportation System) in the United States are on their way to create an air transportation system that meets the demands of the future. Air traffic control is a multi-disciplinary field that attracts the attention of many researchers, ranging from pure mathematicians to human factors specialists, and even in the legal and financial domains the optimization and control of air transport is extensively studied. This book, by no means intended to be a basic, formal introduction to the field, for which other textbooks are available, includes nine chapters that demonstrate the multi-disciplinary character of the air traffic control domain.

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